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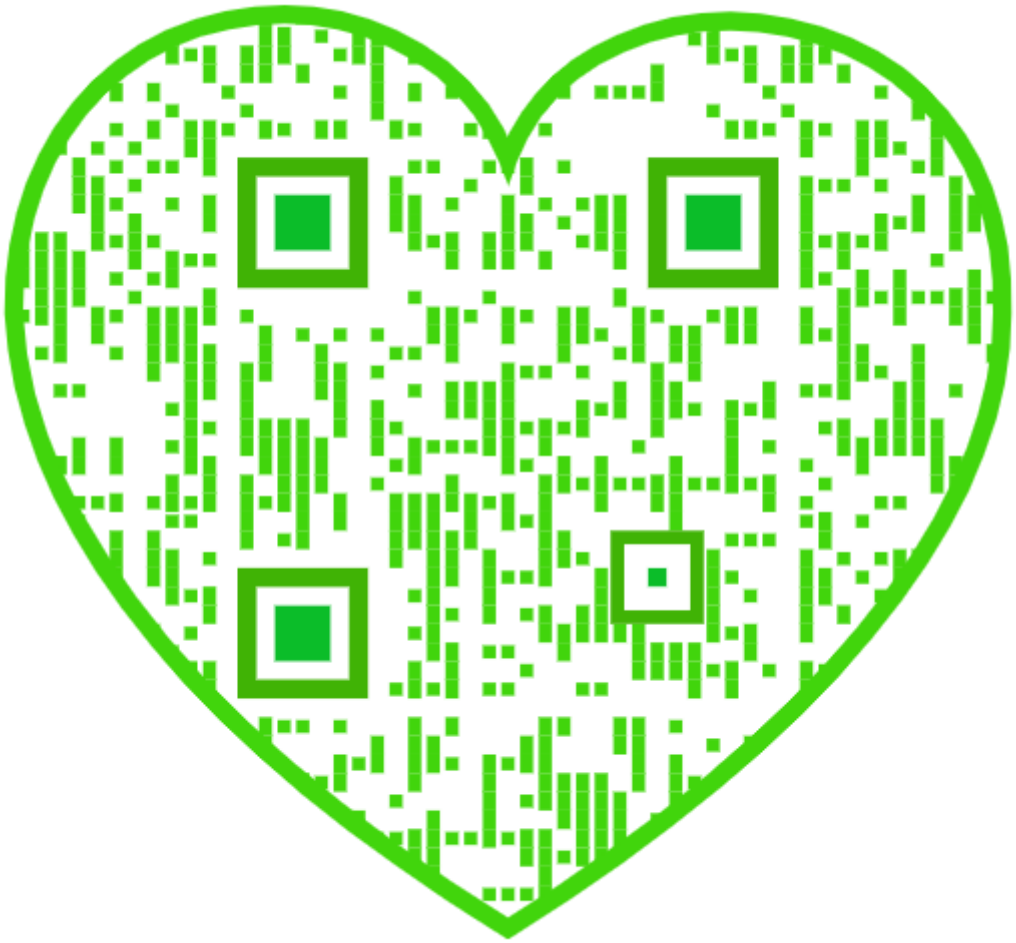

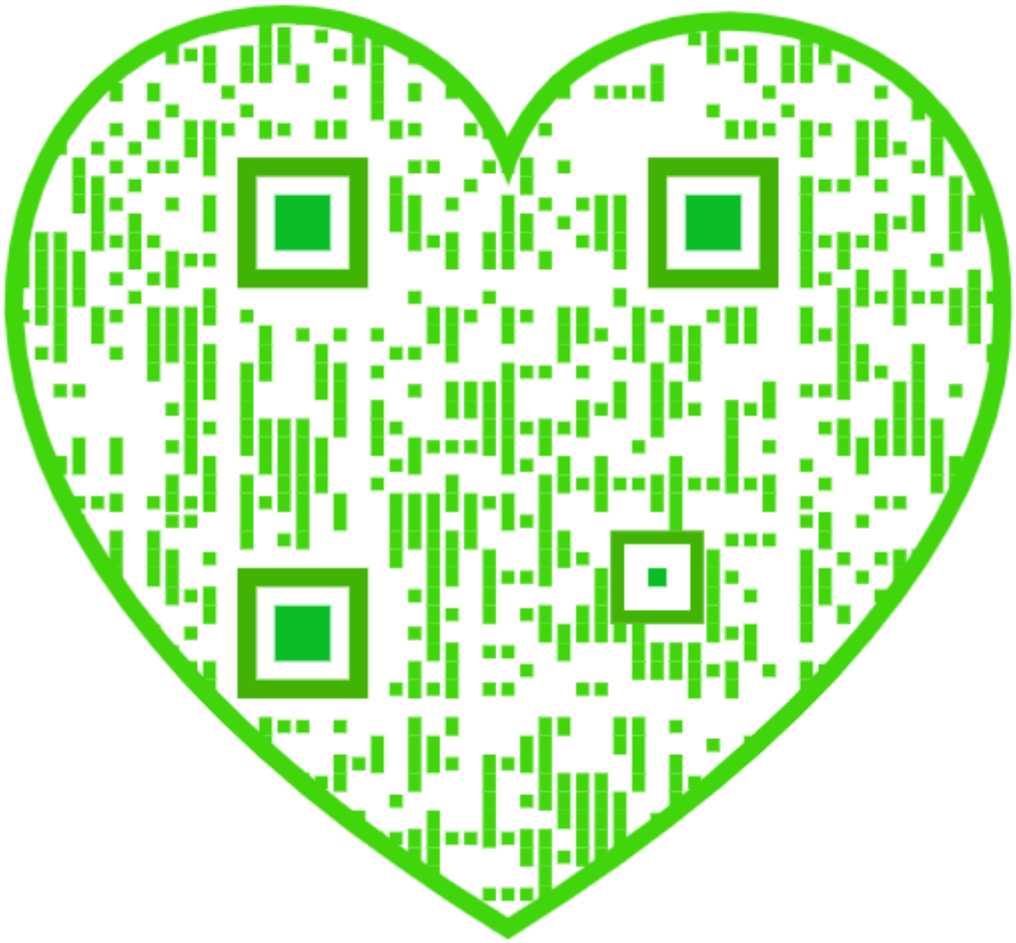

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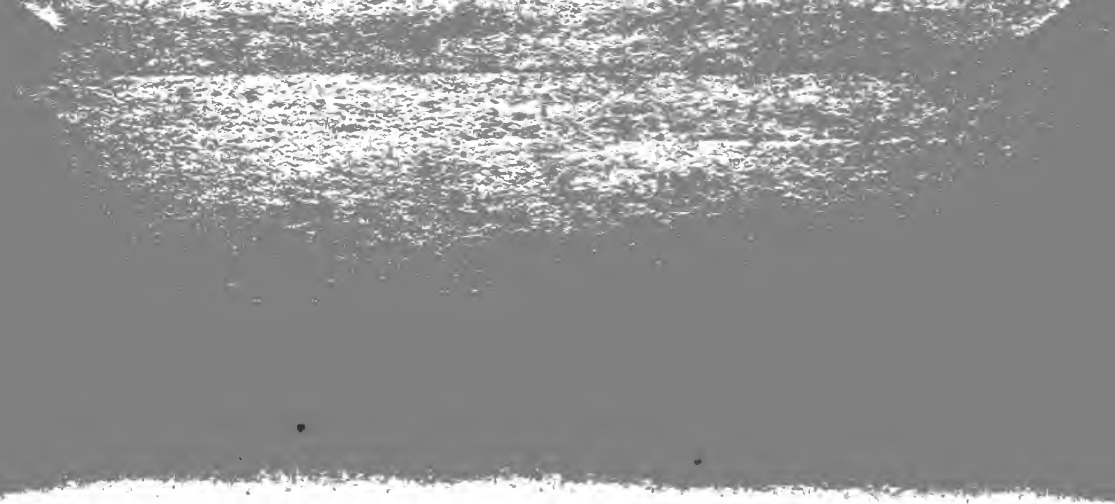


The Watch Balance and its Jeweling

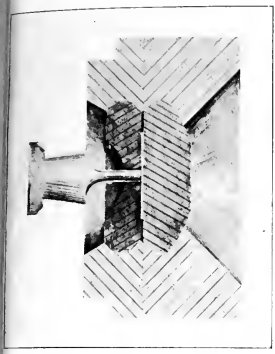
(ILLUSTRATED)

Lecture by C. T. Higginbotham, Supt. South Bend Watch Company, before the State Convention of Iowa Retail Jewelers, at Des Moines, Iowa, June 26th, 1907

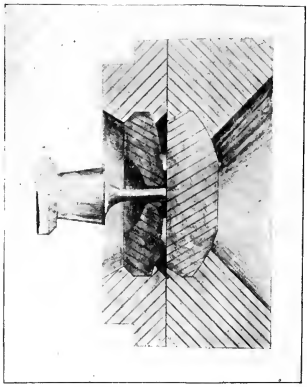
t of capillary attraction. (

(*Page 11*)

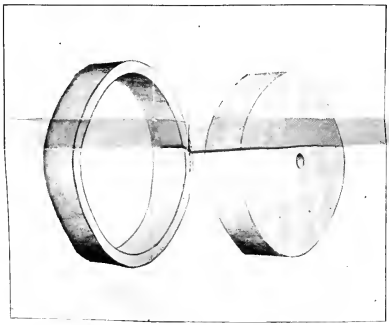
Balance ca



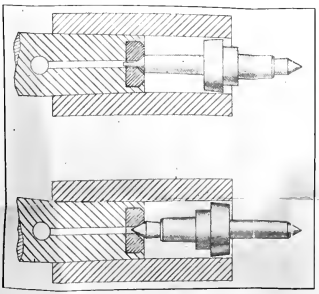
Balance jewel with flat top. (*Page 15*)



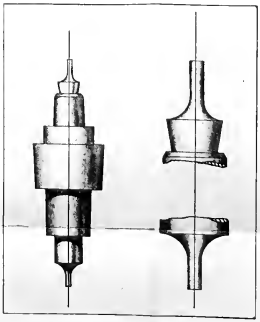
Balance jewel with rounded top. (*Page 15*)



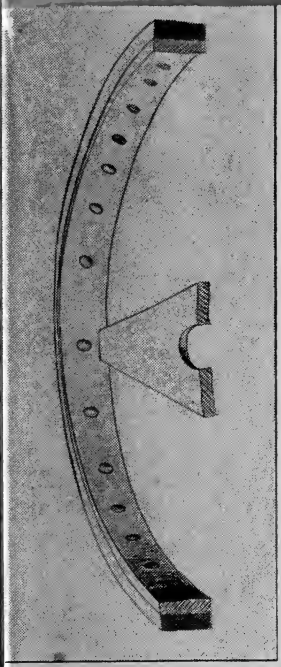
Balance blank and ring. (*Page 8*)



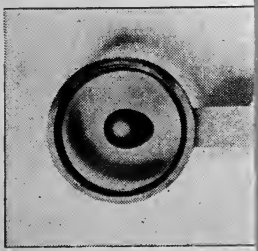
Method of making correct balance staff. (*Page 12*)



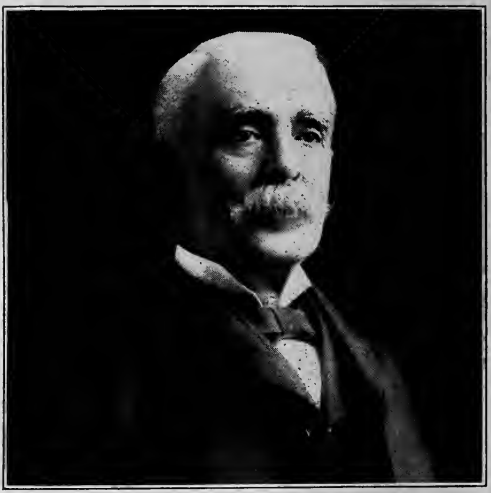
Points out of line. (*Page 11*)



ction of Balance showing the two metals in rim. (*Page 10*)



Device showing effe



CHARLES T. HIGGINBOTHAM

Mr. Higginbotham probably has a more thorough and broader experience in the science of making high-grade watches than any other man in the United States.

Although sixty-five years of age, he takes an active part in all matters that concern the production of a movement that is gaining a reputation as a most accurate and durable timepiece—the South Bend.

THE WATCH BALANCE AND ITS JEWELING

A Lecture by C. T. Higginbotham, Supt. South Bend Watch Company, before the State Convention of Iowa Retail Jewelers, at DesMoines, Ia., June 26, 1907.

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This little booklet contains the first of a series of lectures delivered by Mr. Higginbotham before various Conventions of the Retail Jewelers' Associations, and is passed to you, feeling it might be of interest.

Gift
Author
(Person)
MAR 27 1915

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THE balance is the heart of the watch. As the heart controls and regulates the flow of blood through the human system, so the balance controls and regulates the flow of power through the train and escapement of the watch. As the physician in diagnosing the ailment of his patient directs his attention to the pulse beats, so the watchmaker in examining a watch submitted to him for inspection directs his attention to the vibration of the balance; and as a feeble pulse is a certain indication of an enervated condition of the human mechanism, just so surely a sluggish motion of the balance indicates a disordered condition of the watch. And what an enormous amount of work a balance performs. How few of us thoroughly appreciate it. When we say a balance gives 157,680,000 vibrations every year the statement gives but an imperfect idea of the fact. The number expressed is too great to be readily grasped. Let us see if a few comparisons will aid us to a better comprehension of it.

The human heart beats about 65 times a minute; a balance 300 times. Thus it will be seen that a balance beats more than 4¾ times as fast as the human heart. The periphery of an 18 size balance, in describing its vibrations, traverses a distance of more than 9½ miles in 24 hours. This is to say that if the balance were rolled along the ground to the extent of its vibrations it would cover that distance every 24 hours.

If a track were laid around the world at the equator and an engine having six foot driving wheels were placed on this track and run till the wheels had made the same number of revolutions that the balance describes, in one year it would have made 28 complete circuits of the globe.

The motion of a watch train is intermittent. The motion of a balance is practically continuous. Five times every second the train starts up from a dead rest and for an extremely brief space of time moves forward; again coming to a dead rest. Five times every second the balance reverses the direction of its rotation, stopping for so brief a period that it is impossible for the eye to detect the instant of its stoppage. The office of the train is to convey the power stored up in the mainspring barrel to the escapement and by this means deliver these intermittant impulses to the balance. The balance, by its vibrations, determines the duration of the intervals of time between these successive impulses. As accuracy of rate is entirely dependent upon the uniformity of these intervals it follows that all conditions which in any manner affect the motion of the balance must be as favorable as possible. The weight of the balance should be correctly proportioned to the force which impels it. By "weight of the balance" I am not to be understood as meaning its avoirdupois, but what I shall terms its effective weight. By effective weight I mean the force of its momentum in overcoming the resistence of the hairspring. It is obvious that two balances

may be identical in weight, yet being of unequal dimensions, the larger one will—because of the greater distance of its weight from the center—require a hairspring of greater strength to bring it to time. It is also true that two balances may be identical both in weight and diameter, yet one having the mean of its weight further from the center than the other will also require a stronger hairspring. This will be readily understood if we consider the effect upon the time of a watch produced by moving the meantime screws.

When we move a meantime screw we do not alter the weight of the balance nor do we alter its dimensions, but we do change the distance of the mean of its weight from the center and this is what produces the change of rate. There is in every balance a point—or rather circle—somewhere between its center and its periphery where, if all its weight were concentrated, its resistence to the tension of the hairspring would remain unchanged and as a consequence its vibration would be performed in the same time. This point is called the radius of gyration. The law which determines the effect of the radius of gyration is common to all bodies vibrating from or rotating around a fixed point This law enters into the motion of the planetary system: in fact the entire universe. The laws which govern the oscillation of the pendulum are, in this respect, similar but in another respect they differ materially. This difference is in the fact that the resistance offered to the oscillation of the

pendulum is gravity and friction, mainly gravity, as the friction is simply the resistance of the atmosphere. Gravity, however, has no effect on the vibration of a poised balance, the resistance it has to overcome is the tension of the hairspring, the friction of its pivots in their bearings and the resistance of the atmosphere; mainly the tension of the hairspring. The consequence is that a difference in weight has no effect on the oscillation of a pendulum, provided the mean of the weight is located at the same distance from the point of suspension. Two pendulums of different weights will vibrate in exactly the same intervals of time provided the point known as the center of oscillation be the same distance from the point of suspension. The center of oscillation is not the center of gravity, but differs slightly from that point, being a point where if its entire weight were concentrated it would occupy the same time for its vibration. In a balance, however, the time of its vibration is affected, not only by the length of the radius of gyration, but also by its weight. If a balance be too light the extent of the arcs of vibration will be too sensitive to variations of power, which as we all know occur between the winding up and running down of the mainspring; this sensitiveness will very much increase the isochronal error. If too heavy the arcs of vibration will be too short, and the watch will have what is commonly called a poor motion. It is also necessary that the rim should be sufficiently rigid to offer all resistance possible to flexure. A

balance having a arc of vibration of a turn and a quarter develops considerable centrifugal force. The effect of this is to deflect the rim outward and as the motion reverses it springs inward again. This serves to quicken the long arcs of vibration, thus increasing the difficulty of isochronising.

There is so much dependent upon the proper construction of a bi-metalic, or compensation balance, sometimes called chronometer balance, that a brief description of its manufacture will aid us to the better understanding of its functions. The construction of a compensation balance is a triumph of science and mechanical ingenuity. Its functions are twofold—First, by its momentum, in connection with the resistance of the hairspring, to control the motion of the train wheels. Second, by automatically changing the radius of its gyration to compensate for its own expansion and contraction and changing elasticity of the hairspring caused by variations in temperature. This is to say the mean of its weight is automatically insured at the correct distance from the center to overcome this varying tension. It is of the first importance that the two metals, steel and brass, of which a balance is composed should be selected with the utmost care. A freedom from flaws and an absolute uniformity of texture is necessary. Special formulas are used for the mixture of these metals and every process in the manufacture of the balance calls for great precision. The slightest neglect is likely to be disastrous to its efficiency as a means of adjustment.

The brass used in a compensating balance should have twice the co-efficient of expansion as the steel. A strip of this steel is placed under a punch and cut into discs. These discs are called balance blanks. A hole is now drilled in the center of the blank and is carefully opened to exact size. Upon the accuracy of this operation depends to a large extent the truth of the balance. After being once opened it is not touched with a cutting tool of any description until the balance is completed. The blank is now placed upon an absolutely true arbor and the outside turned down to the standard size; a ten thousandth of an inch being taken into account in this measurement. A ring of brass is now formed; the inside of said ring being carefully fitted to the outside of the steel blank.

Both blank and ring are now dipped into a specially prepared flux and are driven together. These are placed in a sort of bottomless cup called a capsule. The metal of which this capsule is composed has a much higher point of fusion than the brass, the object being to retain the brass in position when it is melted. The hole in the steel blank is now filled with a preparation of plumbago to prevent oxidization in the subsequent operation of heating. The embryonic balance is now placed in a muffle and heated until the brass fuses and becomes smelted to the steel blank. After cooling the plumbago is removed from the hole and the balance mounted on an arbor and a turning made on its edge which removes the capsule and a portion of the

brass. In this condition the brass is quite soft and it remains to bring it to the proper density; an operation requiring the utmost care and skill. If not sufficiently compressed the finished balance will be soft and will easily get out of true; if too much compressed the brass will be more or less disintegrated; its cohesion impaired and its action under changes of temperature very uncertain, thus rendering it unfit for adjustment.

The compression of the brass is performed in a machine of special design and construction. This machine is provided with rolls which gradually compress the brass at the same time producing a lamination in its grain which adds greatly to its rigidity. The sides of the balance are now faced off and the steel chambered to nearly the finished depth. It is now placed in a die under a punch and the metal between the arm and rim punched out.

The next operation is the drilling and tapping of the holes in the rim for the reception of the screws. The balance is now finished, polished, the screws placed in position and is ready to be mounted on its staff.

Another method for uniting the blank and ring is to introduce between the two a thin strip of pure silver. It is impossible to secure a perfect fit in this manner. The result is that balances where the metals are united by interposing silver or solder are not usually perfectly united. There are spaces here and there where a perfect union has not taken place. These are called

blow holes. Sometimes they show on a finished balance giving it an unsightly appearance but when even this is not the case they cause irregularity in the action of the rim under temperature changes. It is hardly necessary to say that if both sections of the rim do not expand and contract equally the balance will retain its poise only in the particular temperature in which the operation of poising was performed.

Another method which is pursued by manufacturers for hardening the brass is hammering. The effect of this method is to compress the outer molecules leaving those near the blank much less dense. It is practically impossible to make a rigid balance in this manner, and for two reasons. First, if the hammering is continued for a sufficient length of time to harden the brass entirely through, the compression is carried to the steel blank decreasing its diameter.

This, of course, produces an imperfect balance. The proper proportions of steel and brass in the finished balance are approximately two-fifths steel and three-fifths brass. If the steel is compressed as is the case frequently when the balance is hammered the finished balance will have a smaller percentage of steel. Second. if the brass is hammered to the ordinary extent it will not be hardened entirely through, and the finished turning removing a large percentage of the compressed metal, what remains is almost as soft as before being treated.

We shall now take up for consideration the balance staff.

The steel of which the staff is made should be of a very fine texture. The amount of carbon infused into it should be sufficient to produce a perfectly hard metal under the usual treatment, but an excess of carbon is to be carefully avoided. I shall have occasion a little later on to speak of the danger of too much carbon. The temper should be such that a pivot will break rather than bend. It is rarely that a pivot which has been bent can be straightened to restore it to its normal condition. In our factory we never make the attempt and I should recommend this course in all cases where accuracy of time is the prime object. The balance pivots should be of sufficient length to carry the cone well clear of the jewel; otherwise the oil is apt to run down the staff. They should be of a uniform diameter for a distance of at least one hundredth of an inch from the ends. That is they should be neither front or back taper. This will avoid trouble in variation of side shake and is particularly necessary if the endshake happens to be a little long. Another matter upon which too much stress cannot be laid is that the pivots be absolutely in line with each other. A reference to the sketch will clearly show what is meant.

You will notice a black line running through the center of the staff and also through the center of one pivot but considerably out of center with the other pivot. This is technically called out of line and is invariably the result of a faulty method of manufacture. It can frequently be detected by a rattling sound when the watch is

held to the ear. This should not be confounded with a grinding sound which is due to an entirely different cause; generally a poorly polished pivot, or a rough jewel hole. A balance pivot in this condition will preclude the possibility of perfectly poising the balance and will interfere with the adjustment of the watch.

The best method of making a balance staff is as follows: The spindle is mounted in a tube called a quill. This tube is of sufficient thickness to make it perfectly rigid; cone bearings are provided at both ends. One end of this spindle carries a jeweled center having a V shaped recess surrounded by a ring or shell of metal as shown in the drawing. One of the pointed ends of the staff is pressed into this jewel while the piece is being shellaced into position, during which process the outer end is perfectly trued; one pivot is now ground up and polished, no turning tool being used for this purpose. The staff is now reversed, the pivot just formed being pressed into the jewel center and the other pivot ground up and polished in a similar manner. This secures an absolute alignment of the pivots both with the staff and with each other.

I have spoken of the danger of an excess of carbon in the steel of which the staff is made. You have all doubtless been troubled to some extent by balance pivots cutting into the end stones, termed pitted endstones. The pitting of endstones may be the result of many defects. For instance, diamond powder will pit an end-

stone. A roughly finished or porous endstone will often produce the same result. The cause being that small particles of the stone become detached and mingling with the oil form an abrasive compound.

Oilstone powder or flour of emery will pit an endstone provided it is of soft material such as garnet, but it will not pit a sapphire endstone. No other material should be used in watches. I will now speak of the most fruitful of all causes for pitted endstones, and one which is not generally understood. This is the composition and treatment of the steel itself.

Some years ago exhaustive experiments were conducted to ascertain if possible the source of this most serious and generally unaccountable trouble. In the course of these experiments it was found that certain balance staffs would pit endstones despite the greatest care exercised in the selection of the stone and its finish. Indeed, it sometimes prevailed to such an extent as to pit a diamond. This phenomenon could not be accounted for by any of the then known theories and it was necessary to look to other causes than those mentioned for the trouble. Turning attention to the steel and its treatment the discovery was made that steel possessing a large percentage of carbon, when brought to a very high heat in being hardened invariably, in time, pitted the hardest endstones. The experiments were continued, many of them being repeated over and over again for long periods with the same result.

It is a well known fact that diamond is nothing more than crystalized carbon, and this taken in connection with the results obtained by the experiments just mentioned seems to fully justify the theory that the pitting of endstones may be, and often is produced, by a portion of carbon contained in the steel being transformed by excessive heat into minute diamonds; or at least into crystals having almost as high an abrasive quality. We have since used the utmost care in selecting the steel and in avoiding overheating in the process of hardening, with the result that a pitted endstone is now an extremely rare occurrence with us.

The jewels used in watches are usually garnet, ruby and sapphire. Their hardness being in the order named. Sapphire is next to diamond in hardness and is the only stone that should be used for balance jewels and endstones. Why not diamonds?

We will presume that the diameters of the pivots are properly proportioned to the dimensions and weight of the balance, which for an 18 size may be eleven to twelve hundredths of a millimeter. The proper endshake for a staff is about two hundredths of a millimeter. How measured

The shape of the jewel hole is of the first importance. The best results cannot be obtained where a hole having parallel sides is used for the reason that a very slight thickening of the oil will impede the motion of the balance unduly.

They should be what is known as olive holes as represented in sketch. This shape reduces the retarding effect of thickening

oil to the minimum. The face of the jewel should have a hemispherical oil cup and the back should be well rounded. When in position the distance between the jewel and endstone should be about two hundredths of a millimeter. If this distance is too great the jewel will soon become dry for a reason which I will explain a little later on. It is a very bad practice to allow the jewel and endstone to be in actual contact as you will sometimes find in the cheapest foreign work. This prevents the oil flowing freely about the end of the balance pivot where it is most needed. The advantage of having the back of the balance jewel well rounded and at a slight distance from the endstone is that the balance pivot will by this means be supplied with oil from capillary attraction. The law of capillary attraction causes liquids to seek the narrowest space. If we insert a very small glass tube into a tumbler of water, holding the tube perpendicularly, we shall find that the liquid will rise to a slightly higher point inside the tube than the surrounding surface.

Capillary attraction is the force that causes this phenomenon. If we bring two edges of a couple of plates of glass together allowing the surfaces to slightly diverge from each other and holding them in this position with their contracting edges uppermost insert them in water, we shall find that on withdrawing them a certain amount of water will, in spite of the force of gravity, be retained by the close proximity of the inner surfaces of the glass. The law is the same as that which causes the liquid

to rise in a glass tube. It is the effect of this law which retains oil between the endstone and jewel. Were it not for this natural force the oil would soon flow away from the jewel hole leaving the balance pivot dry. If the upper side of a balance jewel be flat the greater portion of the oil will be drawn between the settings leaving the jewel dry, whereas if the jewel be well rounded the oil will collect at the center and the balance pivots acting as the piston of a pump keep the supply at this point until the last particle is exhausted. The illustration shows a little device which fully illustrates this law.

Avoid putting too much oil to a balance jewel. A super-abundance of oil will either run down the balance staff or find its way between the jewel settings. Excellent results may be secured by moistening with oil the point of a piece of pegwood sharpened to enter the balance jewel hole and with the usual oiling with a steel oil dropper insert the peg into the balance hole. A portion of the lubricant is thus carried to the space between the balance jewel and endstone.

When you have read this little booklet from cover to cover, by passing it to your watch-maker, it might be to your mutual advantage.

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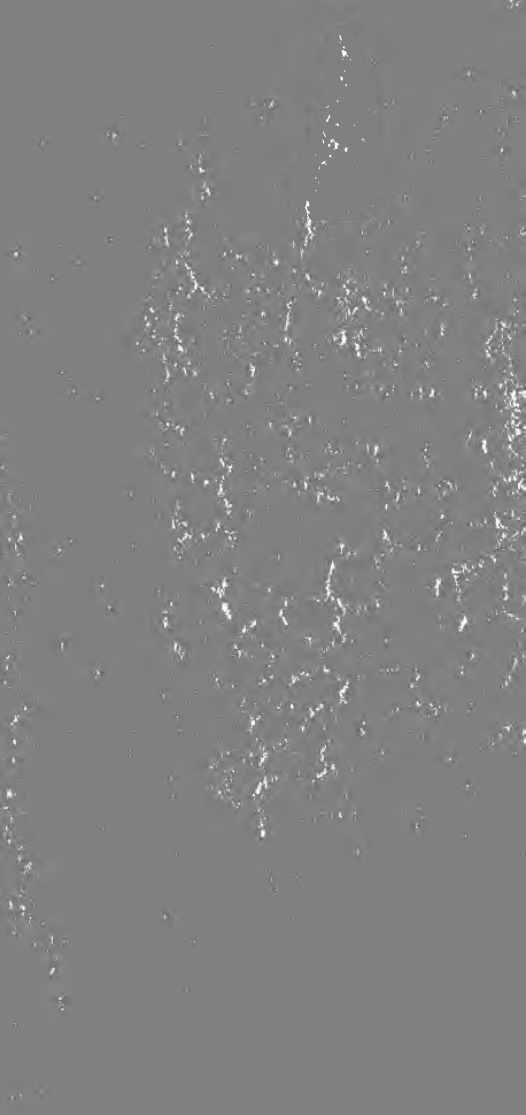

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